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RADIOLOGICAL SURVEY OF PUGET SOUND NAVAL SHIPYARD BREMERTON, WASHINGTON, AND ENVIRONS

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The Eastern Environmental Radiation Facility (EERF) of the U. S. Environmental Protection Agency (EPA), in cooperation with the U. S. Naval Ship Systems Command (NAVSHIPS) has conducted radiological surveillance programs in a number of ports which serve nuclear-powered vessels. These studies were begun in 1961 and have been conducted at ports on the East, West, and Gulf Coasts of the Continental United States and in Pearl Harbor, Hawaii. These studies were undertaken to determine if nuclear-powered vessel operations, including berthing, repair, and servicing, had resulted in environmental radioactivity levels which could contribute a detectable radiation exposure to the public. The survey of the harbor at Bremerton, Washington, in October 1974, was the latest in this series.

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FOREWORD

The Office of Radiation Programs carries out a national program designed to evaluate the exposure of man to ionizing and nonionizing radiation, and to promote the development of controls necessary to protect the public health and safety and assure environmental quality.

Technical reports allow comprehensive and rapid publishing of the results of Office of Radiation Programs' intramural and contract projects. The reports are distributed to State and local radiological health offices, Office of Radiation Programs' technical and advisory committees, universities, laboratories, schools, the press, and other interested groups and individuals. These reports are also included in the collections of the Library of Congress and the National Technical Information Service.

I encourage readers of these reports to inform the Office of Radiation Programs of any omissions or errors. Your additional comments or requests for further information are also solicited.

W. D. Rowe, Ph.D.
Deputy Assistant Administrator
for Radiation Programs

PREFACE

The Eastern Environmental Radiation Facility (EERF) participates in the identification of solutions to problem areas as defined by the Office of Radiation Programs. The Facility provides analytical capability for evaluation and assessment of radiation sources through environmental studies and surveillance and analysis. The EERF provides technical assistance to the State and local health departments in their radiological health programs and provides special analytical support for Environmental Protection Agency Regional Offices and other federal government agencies as requested.

This study is one of several EERF projects designed to assess environmental radiation contributions from the operation of nuclear-powered vessels.

Charles R. Porter
Director
Eastern Environmental Radiation Facility

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Introduction

The Eastern Environmental Radiation Facility (EERF) of the U. S. Environmental Protection Agency (EPA), in cooperation with the U. S. Naval Ship Systems Command (NAVSHIPS) has conducted radiological surveillance programs in a number of ports which serve nuclear-powered vessels. These studies were begun in 1961 and have been conducted at ports on the East, West, and Gulf Coasts of the Continental United States and in Pearl Harbor, Hawaii. These studies were undertaken to determine if nuclear-powered vessel operations, including berthing, repair, and servicing, had resulted in environmental radioactivity levels which could contribute a detectable radiation exposure to the public. The survey of the harbor at Bremerton, Washington, in October 1974, was the latest in this series.

This survey differed somewhat from previous ones. Meetings were held with both NAVSHIPS and Puget Sound Naval Shipyard (PSNS) for the purpose of providing EPA personnel with information on past and present shipyard radiological opurations and procedures. All requested information was freely provided verbally and/or written. The information requested was for the purpose of determining sample locations, procedures and types, as well as nuclides and approximate activities to be expected. Based on the information received and that derived from previous studies, EPA independently designed the study to meet the above objectives.

Characteristics of the Puget Sound Naval Shipyard and the Environs

PSNS is located on Sinclair Inlet, an embayment off central Puget Sound, approximately 24 kilometers west of Seattle, Washington. The shipyard is located adjacent to the City of Bremerton, Washington.

The Inlet is approximately 4.8 kilometers long and 1.2 kilometers wide. Inlet water depths at mean low tide range from approximately 6 meters at the southwest end to approximately 27 meters at the northeast end near Port Orchard. Overhaul and repair of nuclear powered vessels at this shipyard was begun in 1967. The silt and core samples collected during the survey and data from United States National Oceanic and Atmospheric Administration

maps indicate that the bottom of Sinclair Inlet is mostly mud with rocks at some locations. Due to the relatively wide, shallow nature of Sinclair Inlet, tidal flushing is very limited. Gorst Creek flows into the southwest end of the inlet but the flow rate is small and does not significantly affect mixing and tidal action. It is estimated that a complete exchange of inlet water occurs every 6 to 12 months (1).

Communication with local authorities indicated commercial fishing is rarely done in the inlet area. However, salmon rearing facilities are located nearby. Sport fishing and shellfishing are popular in the vicinity.

The shoreline in the Sinclair Inlet, Port Orchard, Rich Passage, and other adjacent areas appeared to be utilized primarily for residential, recreational, and industrial-commercial applications. There was no indication of large scale agricultural operations.

Survey and Analytical Methods

The sampling locations covered a large area with concentrated sampling in close proximity of the PSNS. These locations are shown in figures 1 and 2.

An underwater scintillation probe containing a 10 centimeter by 10 centimeter NaI(Tl) detector was used in conjunction with a 400-channel pulse height analyzer in an attempt to delineave areas of radioactivity.

Twenty-minute counts were taken and a background spectrum from location 1 (Liberty Bay) subtracted from each spectrum. Locations of probe counts taken in the vicinity of the shipyard are indicated in figure 3.

The underwater scintillation probe has proved useful in previous surveys (2) to quantitatively delineate general areas of radioactivity. The levels of activity encountered in this survey were below the detection limits for the underwater probe. Dredge samples were taken at locations where radioactivity seemed most probable based on the location of various operations within the shipyard.

The Radiological Support Building (Building 439), is located on the south end of Pier 6. Equipment in

Figure 1. Sampling locations in the area

Figure 2. Sampling locations in the harbor

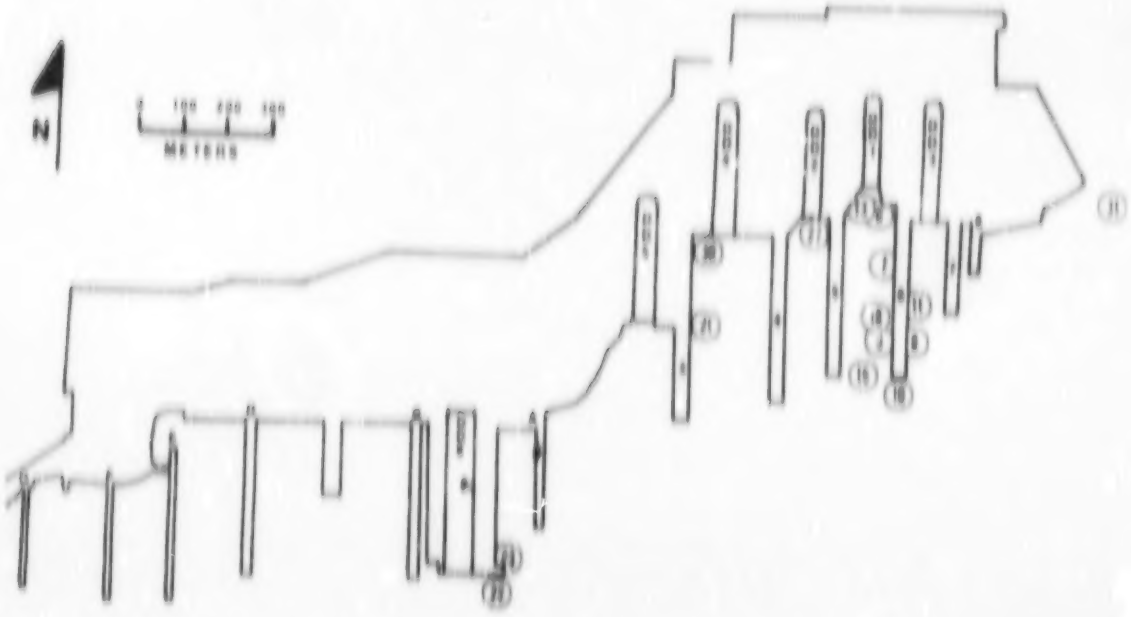

Figure 3. Locations of probe counts taken

the building is used to process and seal radioactive waste into drums for shipment to a commercial waste disposal site. The areas adjacent to the Radiological Support Building were surveyed in greater detail because of the possibility of radioactive waste discharges in this area.

A standard Peterson dredge was used to sample approximately the top 10 centimeters of sediment. The samples were dried at 110° C, ground to a fine powder, placed in a 400 cm³ "cottage cheese container", and counted on a 10 centimeter by 10 centimeter NaI (Tl) detector or a 40 cm³ Ge(Li) detector.

Sediment core samples were collected by divers at several locations. The purpose of the samples was to define the vertical distribution of any radioactivity in the bottom sediment. These samples were collected by pushing a 2.5-centimeter diameter by 61-centimeter tube into the sediment as far as possible and then capping the ends of the tube. In the laboratory the cores were frozen and then cut into 2.5-centimeter sections and counted in the wet state on either of the gamma detectors mentioned above.

Vegetation samples (moss and kelp), were collected as available in the area of the shipyard. They were generally found on rocks and piey pilings. These samples were dried at 110° C, ground to a fine powder, and analyzed for gamma-emitting radionuclides.

Water samples were collected and analyzed for gamma emitters and tritium.

Fish samples collected at several locations were also analyzed for gamma-emitting radionuclides. These samples were cut and packed and counted in 400 cm³ "cottage cheese containers."

Two air samples were collected specifically for the determination of krypton-85 and tritium. Also air samples were taken to determine the presence of any gamma emitters. The three procedures used for this collection are as follows:

1. The sample for krypton-85 analysis was collected adjacent to the Radiological Support Building by compressing 1 m^3 of air into a tank. The analysis of this sample was done by cryogenically removing the krypton and counting by liquid scintillation (3).

2. The samples collected for tritium determination were also collected adjacent to the Radiological Support Building. A low volume vacuum pump and drierite columns were used for the collection. The analysis was performed by equilibrating the drierite with water and analyzing the water for tritium.

3. The samples collected for the analysis of gamma emitters were collected at the Radiological Support Building and the Radiological Offices Building (Building 495). Building 495 was chosen because of its close proximity to the Radiological Support Building. A High Volume air sampler and MSA Dust Filters were used for collection.

External radiation exposure measurements were made at several locations using a pressurized ionization chamber (PIC) (4). Particular interest was given to the boundary of the PSHS since these areas are accessible to the public.

Results and Discussion

All samples were analysed for gamma-emitting isotopes with particular interest in cobalt-60. Past surveys have shown that cobalt-60 is the predominant radioisotope resulting from nuclear operations. In addition, water samples were analysed for tritium and air samples were analysed for krypton-85.

There is minimal commercial fishing in the area so fish samples were difficult to obtain. Rock cod and several crustaceans were analysed and showed no detectable amount of cobalt-60. No radioactivity above minimum detectable levels was found in any of the sea life samples other than natural activity and a trace amount of cesium-137 (0.02 ± 51%) attributed to fallout. Data from the aquatic life samples are shown in table 1.

Air samples were collected and analysed for tritium, krypton-85, and other gamma emitters. The tritium concentration in these samples was found to be less than the

Table 1

Results of aquatic life sample gamma analyses

Sample Type	Location	Specific Gamma Activity pCi/G Wet Weight		
Sea cucumber	West of Pier 6 (Site 5)	^{137}Cs	0.01	± 56%
		^{40}K	0.60	± 40%
Starfish	West of Pier 6 (Site 5)	^{214}Bi	1.3	± 46%
		^{40}K	1.7	± 30%
Mussels	West of Pier 6 (Site 5)	^{214}Bi	1.2	± 53%
		^{40}K	0.4	± 50%
Crabs	West End of Dry Dock 1 (Site 13)	^{228}Th	0.05	± 76%
		^{40}K	2.1	± 4%
		^{214}Bi	0.02	± 42%
Clams	200 m West of PSNS at shoreline	^{137}Cs	0.01	± 63%
		^{40}K	1.0	± 33%
		^{214}Bi	0.02	± 73%
Rock Cod	Under Pier 6 (Site 9)	^{137}Cs	0.02	± 51%
		^{226}Ra	0.04	± 62%
		^{40}K	3.1	± 19%

minimum detectable level (1 pCi/l). The krypton-85 level was found to be 17.4 pCi/l which is considered to be within average background levels. No samples were taken elsewhere because this is the only area where it was deemed that any possibility of elevated levels of these nuclides existed. The two filters from the high-volume air samples were analyzed for gamma emitters and none were detected. These results are shown in table 2.

Water samples were collected and analyzed for gamma emitters and tritium. No activity above minimum detectable levels was observed in these samples. The minimum detectable level for tritium is 0.2 nCi/l.

Samples of aquatic vegetation were collected in the harbor area and analyzed for gamma-emitting radioisotopes. Only a trace amount of cobalt-60 (0.02 ± 65%) was found in one of the samples. The only activity detected in the other vegetation samples was natural radioactivity and fallout. Results from analysis of these samples are shown in table 3.

Silt samples were taken at 14 locations and trace quantities of cobalt-60 were found in 5 (table 4). These results indicated that releases have taken place in the past. The levels determined are close to the limit of detectability (0.02 pCi/gm) indicating no significant releases have taken place for several years. The locations of the cobalt-60 activity in the shipyard area were expected due to past releases. However, the activity found at site 14 (Dyes Inlet) was unexpected. This activity was probably due to tidal action or possibly a release from another type of facility. The Navy Environmental Impact Statement for the TRIDENT support site on the Hood Canal stated that low levels of radioactivity from the AEC Reactors on the Columbia River could be detected in the Hood Canal marine life (5). The silt sampling locations in the vicinity of the shipyard are shown in figure 4.

Core samples were collected at eight locations (see figure 5) to determine the vertical distribution of radioactivity in the sediment. The predominant activity found was from naturally occurring and typical fallout radionuclides. Only two samples collected at the south end of dry dock 6 had detectable amounts of

Table 2

Results of air sample analyses

Location	Radionuclide	Activity (pCi/l)
On Pier 6 West of Radiological Support Building	^{85}Kr	17.4 ± 10%
Radiological Support Building	^{3}H	0.4 ± 50%
Radiological Support Building	^{3}H	0.3 ± 66%
Radiological Offices Building	----	NDA
Radiological Support Building	----	NDA

NDA = No detectable activity.

Table 3

Results of vegetation sample analyses

Sample Type	Location	Radionuclide	Specific Gamma Activity (pCi/gm)
Moss	West of Pier 6 Site 5	^{95}Zr-Nb	0.14 ± 25%
		^{228}Th	0.05 ± 54%
		^{60}Co	0.02 ± 65%
		^{40}K	1.00 ± 23%
		^{214}Bi	0.72 ± 16%
Kelp	Dry Dock 1 Site 6	^{40}K	10.50 ± 14%

Table 4

Results of silt sample analyses
(Only samples with cobalt-60 activity are shown)

Location	Cobalt, Cesium & Potassium Activity pCi/gm Dry Weight		
Site 07 (West side of Pier 6)	^{60}Co	0.04	± 41%
	^{137}Cs	0.11	± 9%
	^{40}K	8.8	± 6%
Site 08 (East side of Pier 6)	^{60}Co	0.04	± 44%
	^{137}Cs	0.28	± 9%
	^{40}K	7.6	± 6%
Site 13 (Between Pier 6 & 7)	^{60}Co	0.02	± 60%
	^{137}Cs	0.27	± 9%
	^{40}K	8.4	± 6%
Site 14 (Pier tip)	^{60}Co	0.02	± 87%
	^{137}Cs	0.28	± 11%
	^{40}K	10.1	± 6%
Site 18 (Between Pier 5 & 6)	^{60}Co	0.02	± 62%
	^{137}Cs	0.23	± 9%
	^{40}K	8.1	± 5%
Site 19 (Between Pier 5 & 6)	^{60}Co	0.03	± 57%
	^{137}Cs	0.25	± 9%
	^{40}K	10.3	± 5
Site 22 (End of dry dock 6)	^{60}Co	0.07	± 30%
	^{137}Cs	0.15	± 18%
	^{40}K	5.3	± 9%
Site 32 (750 m Southeast of Pier 6)	^{60}Co	0.04	± 74%
	^{137}Cs	0.26	± 15%
	^{40}K	11.8	± 9%
Site 34 (200 m South of Pier 6)	^{60}Co	0.09	± 50%
	^{137}Cs	0.2	± 17%
	^{40}K	9.8	± 9%

Figure 4. Silt sampling locations

Figure 5. Core sampling locations

cobalt-60. A comparison of the silt and core samples is difficult because the levels observed were close to the limits of detectability. The analytical results from the core samples are shown in table 5.

Measurements of the external gamma radiation exposure were made at several locations using a PIC (figure 6). A series of measurements was taken along the industrial security fence on the north edge of PSNS. A series of measurements was also made over water along an imaginary line approximating the shipyard boundary in Sinclair Inlet running approximately 185 meters from the ends of the piers. These locations were chosen because they represented the nearest sites that were accessible to the general public.

Along the industrial fence at the northern and western perimeters of PSNS only one location had a gamma-radiation level which was higher than the gamma background for the area (see table 6). Measurements indicated the average background from cosmic and terrestrial radiation for the area to be 6.6 ± 1.2 micro-roentgens per hour (μR/hr). At the western end of the shipyard, location G1 on figure 6, the gamma radiation level was 8.5 μR/hr. At this location fill material had been used to stabilize the shoreline against erosion, and this material was noted to be a possible source of the elevated exposure.

The series of PIC measurements taken on the inlet off the ends of the piers (E39 through E44) produced gamma-radiation levels which were no different than background levels over water in that area (Table 7).

Measurements E1 through E38 were made between and adjacent to the piers and dry docks of the shipyard (figure 6). At locations E20 through E21 and locations E27 and E28, elevated gamma radiations were evident. The source of these elevated readings appeared to be the Radiological Support Building.

Table 5

Results of core sample analysis
(Only samples with detectable cobalt-60 are shown)

Location	Depth Below Sediment Water Interface (cm)	Activity pCi/gm Dry Weight
Site 22		
End of dry dock 6	2.5	^{60}Co 0.07 ± 60% ^{137}Cs 0.44 ± 17% ^{40}K 1.85 ± 23%
Site 23	5.0	^{60}Co 0.02 ± 16% ^{137}Cs 0.09 ± 64% ^{40}K 7.58 ± 25%

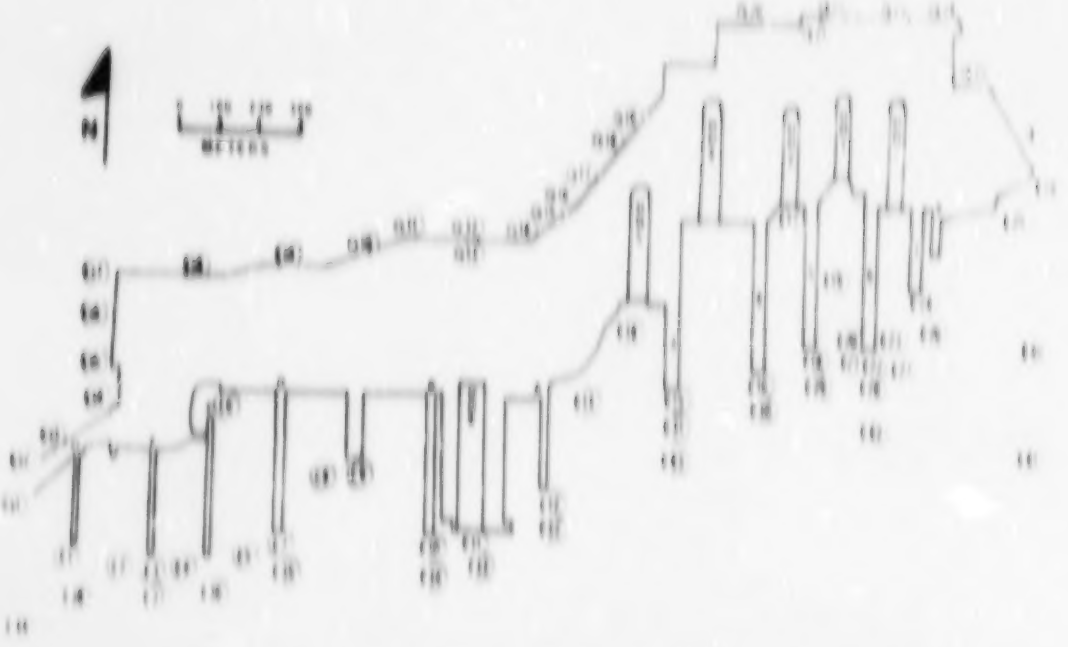

Figure 6. Locations of external gamma radiation measurements

Table 6

Exposure measurements observed over land

PIC Data

Location	μR/hr	Location	μR/hr	Location	μR/hr
G01	6.5	G12	6.9	G23	7.3
G02	6.3	G13	6.7	G24	7.1
G03	5.7	G14	6.7	G25	5.9
G04	5.9	G15	6.5	G26	6.3
G05	5.9	G16	6.9		
G06	6.5	G17	6.7		
G07	6.9	G18	6.5		
G08	6.7	G19	6.7		
G09	6.9	G20	6.9		
G10	6.5	G21	6.7		
G11	6.9	G22	6.7		

Table 7

Exposure measurements observed over water

PIC Data

Location	μR/hr	Location	μR/hr	Location	μR/hr
E01	4.5	E16	4.7	E31	4.5
E02	4.5	E17	4.7	E32	4.5
E03	4.3	E18	4.7	E33	4.5
E04	4.7	E19	4.9	E34	4.7
E05	4.5	E20	9.9	E35	4.5
E06	5.1	E21	18.3	E36	4.5
E07	4.7	E22	10.4	E37	4.3
E08	4.5	E23	9.5	E38	4.5
E09	4.5	E24	4.9	E39	4.7
E10	4.3	E25	4.5	E40	4.5
E11	4.5	E26	4.7	E41	4.5
E12	4.5	E27	6.3	E42	4.3
E13	4.7	E28	7.3	E43	4.3
E14	4.9	E29	5.5	E44	4.7
E15	4.5	E30	4.7		

Conclusions

As a result of the survey of the Puget Sound Naval Shipyard, the following conclusions can be drawn:

1. The results of this study indicate the procedures utilized by the Navy to control the release of radioactive material into the Bremerton Harbor from PSNS are apparently effective.

2. Levels measured are close to the detection limit for the most sensitive analytical equipment. This indicates that nuclear operations at the Puget Sound Naval Shipyard are not contributing a significant radiation exposure to the public.

3. External exposure measurements in public areas indicate no exposures above natural background resulting from PSNS operations.

The continuation of the current practices regarding waste discharge and the Navy monitoring program should assure continued absence of significant public exposure for routine nuclear ship operations.

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